Electronic Supplementary Information

Room-Temperature Crystallization of Hybrid-Peroxskite Thin Films via Solvent-Solvent Extraction for High-Performance Solar Cells

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Supplementary Figures:

Fig. S1. Photographs of the SSE process in DEE bath: (A) as-spin-coated MAPbI₃ precursor thin film, (B) during SSE (2 s), and (C) after SSE (2 min).

Fig. S2. Sequence of photographs after dropping a spin-coated MAPbI₃ precursor thin film (patterned) in DEE bath showing rapid MAPbI₃ perovskite thin film formation.

Fig. S3. Sequence of photographs after adding drops of MAPbI₃ precursor solution (in NMP) in DEE bath showing sluggish MAPbI₃ perovskite precipitate formation.
**Fig. S4.** Cross-sectional SEM images of MAPbI$_3$ perovskite films of various thicknesses deposited on TiO$_2$-blocking-layer coated FTO-glass substrates using the SSE process at room temperature: (A) ~50 nm, (B) ~80 nm, (C) ~250 nm, and (D) ~410 nm.

**Fig. S5.** Cross-sectional bright-field TEM image of a ~20-nm MAPbI$_3$ perovskite film deposited on TiO$_2$-blocking-layer coated FTO-glass substrate.
**Fig. S6.** Bright field TEM images of a typical MAPbI$_3$ perovskite-based solar cell, where the MAPbI$_3$ thin film (~700 nm thickness) is deposited using the SSE process at room temperature: (A) overall view, (B) detailed view of region ‘B’ showing hole-transporting material (HTM) and MAPbI$_3$, (C) detailed view of region ‘C’ showing MAPbI$_3$ grains, and (D) detailed view of region ‘D’ showing MAPbI$_3$, TiO$_2$ blocking layer and FTO. The thickness of the MAPbI$_3$ layer in this solar cell is unusually thick, and Au was used as the top contact instead of the Ag used in the other cells.

**Fig. S7.** Elemental EDS mapping of the solar cell in Fig. S6 showing the distribution of elements Sn, Ti, Pb, I, and Au.
Fig. S8. Optical properties of MAPbI₃ perovskite films of various thicknesses deposited on TiO₂-blocking-layer coated FTO-glass substrates using the SSE process at room temperature: (A) transmission, (B) reflection, and (C) absorption. Inset in (B) are photographs of the films.

Fig. S9. J-V characteristics of a PSC based on 250-nm SSE MAPbI₃ perovskite thin film, under simulated one-sun AM 1.5G (100 mW cm⁻²) illumination, in forward (normal) and reverse scan.
Fig. S10. Mean, minimum and maximum PCE values of PSCs tested under simulated one-sun AM 1.5G (100 mW cm$^{-2}$) illumination (0.16 cm$^2$ typical active area) as a function of SSE MAPbI$_3$ perovskite film thickness. About 10-20 solar cells were tested for each thickness.

Fig. S11. (A) Typical Nyquist plots of the impedance responses for a solar cell made from SSE MAPbI$_3$ film of ~250 nm thickness, with three different bias voltages. The impedance spectra are dominated by a large semicircle at low frequencies. (B) Plots of recombination resistance as a function of voltage for solar cells with different thickness SSE MAPbI$_3$ perovskite films.
Fig. S12. (A) XRD pattern and (B) SEM micrograph of top surface of 250-nm SSE MAPbI₃ perovskite thin film that has been heat-treated at 100 °C for 15 min in air.

Fig. S13. Mean, minimum and maximum PCE values of PSCs tested under simulated one-sun AM 1.5G (100 mW cm⁻²) illumination (0.16 cm² typical active area) as a function of annealing heat-treatment (100 °C, 15 min, in air) of SSE MAPbI₃ perovskite films (~250 nm thickness). About 10-20 solar cells each were tested.